EFFECT OF NUTRIENT SOLUTION WITH DIFFERENT N:K RATIOS ON THE YIELD OF CLAUDIUS F1 SPROUTED PEPPERS IN CONTAINER CULTIVATION

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Abstract. *Today, there is a growing trend towards growing peppers in foil or glasshouse, rather than in the open field. The advantage of these over open field cultivation is that they can increase the yield, improve the quality of the crop and the timing of the production, which in turn gives a much higher yield security. The most popular and least expensive investment for growing under foil is container growing. The aim of my research was to study the yield of the pepper variety Claudius under different nutrient solution formulations. I applied four treatments, which consisted of four different nutrient solution compositions. The first treatment had a nitrogen to potassium ratio of 1:1, the second treatment 1:1.3, the third treatment 1:1.6 and the fourth treatment a N:K ratio of 1:2. Each treatment was repeated four times. Each treatment involved 80 plants, which is 20 plants per replicate. During the experiment, I found that the different nitrogen/potassium ratios of the nutrient solution affected not only the weight of the harvested fruits, but also the number of fruits. A higher potassium content relative to nitrogen will clearly change the plants in a generative direction due to the upsetting of the vegetative-generative balance. The fruits started to reach the red colour typical of biological maturity before reaching the shape and size typical of the variety.*

Keywords*: pepper (Capsicum annuum L.), nitrogen, phosphorus, potassium, nutrient solution, yield*

INTRODUCTION

Our country is one of the largest producers of paprika in the European Union (TERBE - SLEZÁK, 2008). In Hungary, peppers are the most widely cultivated vegetable in sprouts, with a cultivated area of about 2250 hectares (KICSKA, 2016). In recent years, outdoor cultivation has been increasingly marginalised, while sprouting has become more popular. It is expected that the area of field pepper production will continue to decrease (TERBE - HODOSSI - KOVÁCS, 2005). The main reasons for this may be the weather, which has become more extreme in recent years, and another important reason is the availability of crop safety, as it is much easier to ensure optimal conditions for the plants in the sprouting system. However, it is also important to take into account the need to select a variety that can adapt to these growing conditions (Széll, 2002). Another very important aspect is the timing of the production of vegetables for the market, which can only be done efficiently in a greenhouse.

To develop one kilogram of pepper, the plant needs 2.4 g nitrogen (N), 0.4 g phosphorus (P_2O_5) and 2.9 g potassium (K_2O) (TERBE - SLEZÁK, 2008). Nutrient requirements also depend on the variety, environmental factors, yield and age of the plant. KAPPEL - TERBE - SZABÓ (2006) estimated the specific nutrient requirements for edible peppers as follows: nitrogen (N): 2.4-3.8 kg/t, phosphorus (P_2O_5): 0.7-1.1 kg/t, potassium (K_2O): 4.9-6.9 kg/t. The need for macro-nutrients is indisputable, but in the case of micro-nutrients, it is not possible to single out just a few, as paprika is sensitive to deficiencies of all micro-nutrients (GYULAI - SEBESTYÉN, 2011). Peppers do not require any nutrient supplementation from the time of emergence until the first leaves appear, as they are still feeding on the seeds. The nutrient content of the growing medium should be increased only after rooting has started (TERBE, 2007). The nutrients applied during seedling establishment are of particular importance, as a balanced supply of nutrients determines the success of subsequent cultivation (OMBÓDI - LOCHER - DIMÉNY, 2003). The uptake of nutrients is not only influenced by their form in the soil, but also by the soil pH. Most nutrients are no longer available to plants above pH 6.5 (slightly acidic). With the exception of molybdenum, most micronutrients are more readily absorbed the more acidic the soil (SÁRDI, 2011).

To make a nutrient solution, the solid fertiliser is dissolved to make a stock solution, which is usually diluted 100-fold immediately before use. It is always advisable to make only enough stock solution to cover one day's needs. To avoid precipitation of nutrient solutions, separate containers are used for each nutrient. According to ZATYKÓ - MÁRKUS (2006), tank „A" should contain $Ca/NO_3/_2$; nitric acid; KNO_3; NH_4NO_3; and iron. Tank „B" may contain phosphoric acid; K_2SO_4; $MgSO_4$ and trace elements, and tank „C" may contain the acid needed for pH adjustment.

MATERIAL AND METHODS

The experiment was carried out in 2019 in my place of residence, Pusztaföldvár (Békés county, Hungary) in my own foil tent, which is a 7m wide, 50m long, 3.1 m high, double-walled, unheated foil tent. This greenhouse is equipped with a humidification device and windows and doors for proper ventilation, which I closed with insect nets to prevent the entry of pests. Since I chose to grow the plants in a support system, I stretched wire mesh in the greenhouse along the rows, both longitudinally and transversely.

NÉMETH (2015) has classified white pepper varieties into three growth types, which is a key criterion for growers in selecting varieties. Based on these, we distinguish between generative, balanced and vegetative growth types. For my experiment, I chose the sweet, white, long pepper variety Claudius F1, marketed by Orosco Ltd. The variety produces medium-mature, large, which is a much sought-after product on the market, and is not susceptible to thrips. Orosco, the seed distributor, recommended this variety mainly for unheated foil production and intensive field conditions.

I bought peat for sowing and sowed the seeds on 12 March 2019. After the appearance of the first leaves, I watered the seedlings with 0.3% Volldünger Linz (N:P:K - 14:7:21) fertilizer once a week, supplemented with superphosphate. The planting was done on 21 April 2019 in the unheated large airspace foil tent. Since I did not plant the plants in the soil, but chose to grow them in containers, I did not consider it necessary to use a soil disinfectant. The growing medium consisted of a mixture of 50% "marosi" gravel and 50% "pötrétei" peat, with the addition of a rooting fertiliser 3kg/m3 18% superphosphate.

The fertilization was carried out with Volldünger Linz, a complex solid fertilizer with a N:P:K - 14:7:21 ratio, applied as a nutrient solution at a concentration of 0.3 g/litre. The plants in the treatment were arranged in a twin row arrangement. Thus, there were 4 rows of twins, representing 4 different treatments, illustrated in Figure 1 by different colour coding. I placed the containers so that the plants in the twin rows formed had a staking distance of 18cm. The number of plants per square metre was 7.6 plants. As all plants were placed in the same foil house, there were no significant differences in temperature, humidity and light conditions, and pruning and plant protection were done in the same way for all plants. The plants in the rows marked in blue in Figure 1 are referred to as treatment 1 plants further in the experiment, where the N:K ratio of the nutrient solution composition was 1:1. The N:K ratio of the nutrient solution of treatment 2, marked in yellow, was 1:1.3. The green colour indicates the plants in treatment 3, where I applied a 1:1.6 N:K nutrient solution. The grey colour indicates the last treatment of the experiment, where the N:K ratio of the nutrient solution was 1:2. Each treatment was repeated four times. Each treatment involved 80 plants, which means 20 plants per replicate. The nutrient solutions were usually applied 3 times a week. I watered more frequently at lower rates in hot weather and less frequently in cloudy weather. In the summer heat I also watered the plants with clean water to cool them down.

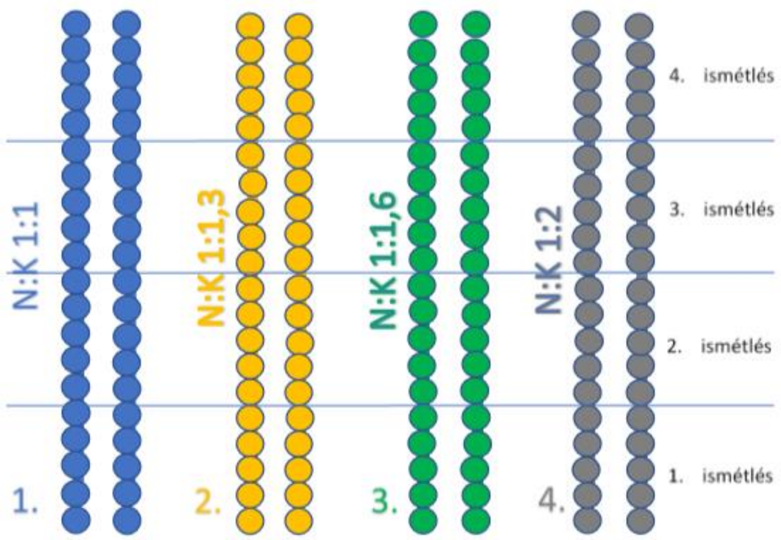

Fig. 1. Placement of containers in the foil tent (own editing)

I prepared the basic nutrient solution with Volldünger Linz complex water soluble fertilizer. I used 100 litre containers for mixing and storing the four different proportions of the nutrient solution. This tank size is suitable for a single application. I prepared a new nutrient solution immediately before each replenishment. The components of 1 kg of Volldünger Linz fertiliser are, by weight: 14% N (5.3% NH_4 and 8.7% NH2). P_2O_5 is 7%, K_2O 21%, Mg 1% and microelements (B, Cu, Mn, Fe, Zn) 1%. The same in grams: 140g N (53g NH4 and 87g NH_2), 70g P_2O_5, 210g K_2O, 10g Mg and 10g microelements. The nutrient calculations are based on the atomic weight of the elements. 140g N contains: 53g NH4, which is 41.2g nitrogen and 87g NH_2, which is 76.12g nitrogen (total 117.32g N). 70g P_2O_5 contains: 30.56g P. 210g K_2O contains: 174.33g K. If I dissolve 10g of Volldünger Linz fertilizer in 10 litres of water for nutrient solution, the nutrient content of the solution is: 1.4g N (of which 0.53g NH_4 and 0.87g NH_2), for a total of 1.1732g N (1173.2mg)/10 litres. 0.7g P_2O_5 contains 0.3056g P (305.6mg)/10 litres. 2.1g K_2O contains 1.7433g K (1743.3mg)/10 litres. For the first treatment, I adjusted the ratio of nitrogen to potassium to 1:1, so I increased the nitrogen content with pesticide. I used Genezis branded pesticide (NH_4NO_3 + $CaMg(CO_3)_2$) with a nitrogen content of 27%. As the amount of nitrogen (1.1732g/10 litres) was increased to an amount equal to the amount of potassium, the addition of 0.5701g of nitrogen was necessary. This amount is present in 2.0360g of pétisone. The potassium level was increased by adding Korn Kali brand potassium sulphate fertiliser containing the following ingredients: 40% K_2O, 6% MgO, 4% Na_2O, 12.5% SO_3. The nitrogen:potassium ratio for the second treatment was 1:1.3. So, to 10 g of Volldünger I added 0.59 g of pesticide fertilizer containing 0.340 g of nitrogen active ingredient, making the ratio 1:1.3, since Volldünger Linz is potassium-rich. This amount is also needed for 10 litres of solution. For the third treatment, the ratio of nitrogen to potassium in the nutrient solution was 1:1.6. Here, in addition to the 10 g of Volldünger, 0.1338 g of potassium was applied. This amount is present in 0.1611g potassium sulphate. In the fourth treatment I changed the ratio to 1:2. If I take the 10g of Volldünger with 1.743g of potassium, I need 0.603g of potassium active ingredient on top of that to get the 1:2 ratio. This amount is found in 0.7263g K_2O. Peppers are known to be a calcium-demanding crop, so its supplementation is very important, especially during the growing season, without which the young buds will be damaged and the crop will show spotting and tip rot (LANTOS, 2007). Calcium promotes longitudinal growth, cell elongation and cell proliferation. It also plays an important role in the structure and permeability of cell membranes (LOCH - NOSTICZIUS, 2004). To avoid precipitation, calcium was not applied with the other nutrients but as a foliar fertilizer. I used Fitohorm brand calcium solution containing 12% nitrogen and 21% CaO. The amount of water used for irrigation was adapted not only to the development of the plant but also to the weather conditions.

The aim of my experiment was to determine which treatment produced the marketable crop with the most varietal characteristics and the fewest second and third class yields. I analyzed the results using one-factor analysis of variance. A result can be said to be statistically significant if $p \leq \alpha$ (Závoti, 2010), and in the case of my experiment it shows that there is some relationship between the nutrient solution used in each treatment and the measured yield results, i.e. between qualitative and quantitative traits.

RESULTS AND DISCUSSIONS

Harvesting was done from 14 July to 13 November 2019, 13 times in total. The distribution of the yields of the treatments per harvest is shown in Figure 2.

In the first treatment I harvested a total of 101533g of crop. I harvested between 8517g and 8939g in the first three harvests, and then an increasing trend was observed in the following harvests. The maximum was 10985g in the month of August. A significant decrease in yield was observed after the mid-September harvests.

In the second treatment, I measured the highest yield, totalling 120633g. Of this, 13348g was harvested at the fourth picking. There was a slight decrease thereafter and then an increase at the first picking in September, when the total yield of the treatment was 12789g. At the following harvests the yield was steadily reduced. The last harvest, on 13 November, was 2541g.

The third treatment was the most evenly distributed. I harvested a total of 115023g. At the first picking 9234g and then this quantity showed an increasing trend until 15 August when the harvested quantity was 12298g. Thereafter a steady decrease was observed. The final harvest was 2232g.

The fourth treatment harvested the lowest yield, with a total of 95446g harvested from the four replicates. Here we see an increasing trend until the beginning of August. The highest quantities in this treatment were recorded on 4 and 15 August, 10997g and 10756g respectively. From 27 August onwards the yield reduction was steady and small. A significant reduction was observed in the last three pickings. The total yield measured at the last harvest was 1784g.

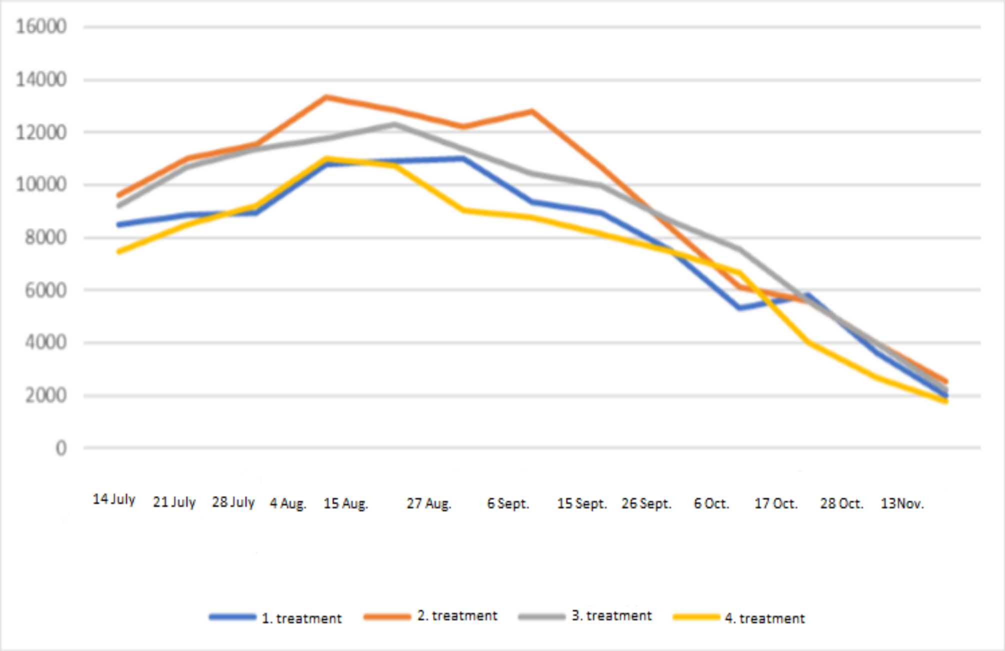

Fig. 2. Distribution of yields by harvest and treatment (own editing)

In Figure 3, I plot the average of the results of the replicates of each treatment for the total harvested crop. This figure illustrates the differences in yield caused by the different nutrient supplementation composition of the treatments. From the plants in the first treatment, where I adjusted the composition of the nutrient solution to 1:1 in terms of nitrogen to potassium ratio, I was able to harvest an average of 25.38kg of crop. The highest results were obtained in the second treatment, with the plants treated with the expected 1:1.3 N:K ratio in terms of total harvested weight. This was 30.16kg in total. The result of the third treatment was not much lower than the previous one, with a total of 28.75kg of peppers harvested. In this treatment I used a nutrient solution with a ratio of 1:1.6. The higher potassium content than applied in the second treatment did not have the most effect on the total harvested yield, but increased the number of fruits to a large extent, thus allowing me to harvest a large but low weight crop. In the fourth treatment I measured the lowest expected yield. Here I changed the N:K ratio to 1:2, which resulted in a low weight but similar number of crops to the first treatment. The total average yield per replicate in the fourth treatment was 23.86kg.

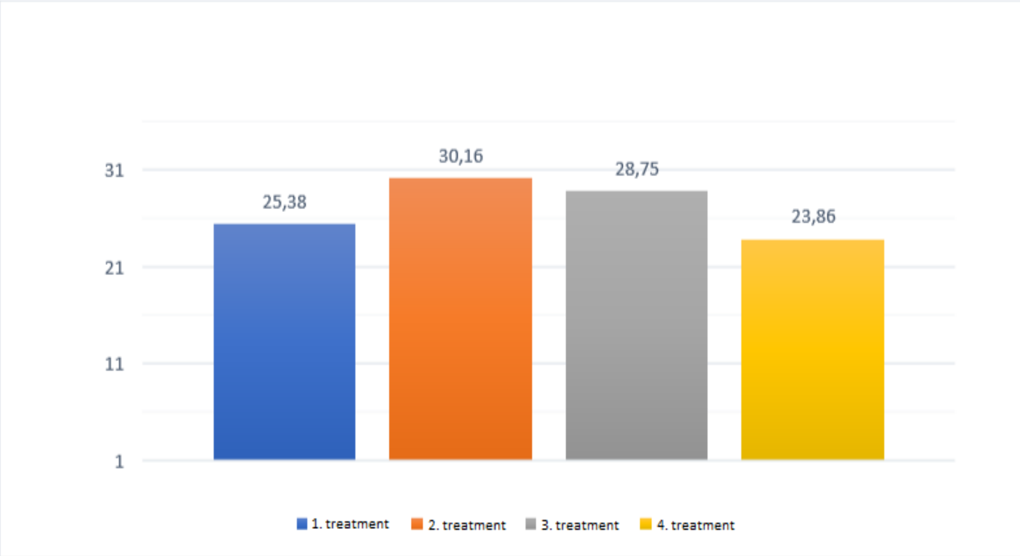

Fig. 3. Total yields harvested in the four treatments (kg) (own ed.)

Increasing the potassium content of the nutrient solution increases the number of fruits, but the results of the experiment show that the weight of the fruits decreases at a nitrogen-potassium ratio of 1:1.6. Figure 3 best illustrates the relationship between fruit weight and number of fruits as a function of different nutrient composition of the nutrient solutions. In the fourth treatment with the high potassium nutrient solution, the lowest fruit weights were measured, but the number of fruits was also reduced compared to the third treatment. The incidence of calcium deficiency and reddening of the fruits also increased with high potassium.

Table 1 shows the analysis of variance of the yields of the treatments, where the p value is smaller than my predefined α value (0.05 or 5%), and therefore a statistically significant difference is observed, i.e. a causal relationship between the results of the nutrient solutions and the measured yields.

Table 1.

Analysis of variance of yields of treatments (own calculation)

Factors	SS	df	MS	F	p-value
Between groups	102059854,2	3	34019951,4	61,23803824	1,51664E-07
Within the group	6666435,25	12	555536,2708		
Total	108726289,4	15			

Table 2 shows the analysis of variance of the results of the treatments (g/piece), which indicates a statistically significant difference in fruit size.

Table 2.

Analysis of variance of g/piece yield of treatments (own calculation)

Factors	SS	df	MS	F	p-value
Between groups	697,0560688	3	232,3520229	39,20200908	1,77267E-06
Within the group	71,124525	12	5,92704375		
Total	768,1805938	15			

CONCLUSIONS

During the experiment, I found that the different nitrogen/potassium ratios of the nutrient solution affected not only the weight of the harvested fruits, but also the number of fruits. Most of the fruit harvested in all the harvests was from the second treatment, where the potassium to nitrogen ratio was 1.3 to 1. In the treatments where I applied nutrient solutions with higher potassium levels, the total harvested yield decreased proportionally in terms of weight with increasing potassium, but fruit numbers increased up to a certain level. On the other hand, plants treated with N:K 1:2 showed a large reduction in the number of fruits. Similar results were reported by SZEPESI - TÓTH - TERBE (2003) in a soil-less stonecrop experiment on Hó F1 white peppers. The results indicate that increasing the potassium content of the nutrient solution in relation to N at a higher dose than 1:1.3 increases the number of fruits but changes the total harvested fruit weight in a negative direction. A higher potassium content relative to nitrogen will clearly change the plants in a generative direction due to the upsetting of the vegetative-generative balance. This may have caused a significant deterioration in the marketability of the fruits when fertilized with N:K 1:2. In this case, I observed fruits that were weaker than most first class crops, and calcium deficiency in the fruits was most frequent here. The fruits started to reach the red colour typical of biological maturity before reaching the shape and size typical of the variety.

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